KU /12 APP /6 TIPS /12

Celestial Mechanics Quiz Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Part A: True or False [12 marks]**

|  |  |
| --- | --- |
| 1. The total energy of each of the planets in our solar system is negative. | True |
| 1. The gravitational energy of a pencil on a desk is higher than the gravitational energy of a pencil on the floor. | True |
| 1. As a penny falls, its binding energy decreases | False |
| 1. As a penny falls, its gravitational energy decreases | True |
| 1. As a penny falls, its total energy decreases | False - law of conservation of energy says total energy of a closed system is always constant |
| 1. To raise a book up to a high bookshelf takes work. | True |
| 1. Binding energy is zero if the total energy of the system is positive. | True. You are not bound if your total energy is positive, so your binding energy (energy needed to get to infinity) is zero. |
| 1. Binding energy is the work done raising an object from one height to another. | False. Binding energy is the energy needed to send an object to infinity |
| 1. A football thrown during a football game has a binding energy that is less than its kinetic energy. | Very false, unless the ball was thrown very, very far. If the ball has Ek>Eb then it will reach infinity. |
| 1. A person on the first floor has a higher binding energy than the same person on the tenth floor. | True because it takes more energy to send a person from the 1st floor to infinity |
| 1. On an ideal rollercoaster, the total energy of the cart is greatest at the top of the highest hill. | False. Law of conservation of energy - the total energy never changes. Think of it this way, at the top of the hill, the cart has low Ek but high Eg. |
| 1. On an ideal rollercoaster, the total energy of the cart is greatest at the bottom of the highest hill. | False. Same reason as above. The cart has high Ek but low Eg. Et is constant. |

**Part B: Application [6 marks]**

1. A geology satellite of mass 3500kg orbits at an altitude of 185km above the Earth's surface. Find the speed of the satellite. [3]

For a satellite: use Fnet = mac­  or Ek = -1/2 Eg

Ek = -1/2 Eg

1/2 mv2= -1/2 GMm/r

v = √(Gm/r)

= √(6.67e-11 x 5.97e24 / (6.36e6 + 0.185e6))

= 7800 m/s

Fnet = mac

Fg = mv2/r (only 1 force)

GMm/r2 = mv2/r

GM/r = v2

v = √(Gm/r)

= √(6.67e-11 x 5.97e24 / (6.36e6 + 0.185e6))

= 7800 m/s

1. The moon has a mass of 7.35x1022kg and a radius of 1.738 x 106m. Find the work done to lift a 30kg mass from the ground to a height of 75m on the moon. [3]

Local:

Fg = mg = GMm/r2

so g = GM/r2

g = 6.67e-11(7.35e22)/(1.738 x 106)

g = 1.62 m/s2

W = mgh

= (30)(1.62)(75)

= 3652 Joules

About 3700 Joules

Universal:

W = ΔEg = GMm[ 1/R1 - 1/R2]

W = 6.67e-11(7.35e22)(30)[ 1/1.738e6 - 1/1.738 075e6]

W = 1.471e14 [2.483e-11]

W = 3652 Joules

About 3700 Joules

**Part C: Thinking Questions [12 marks]**

1. Let A and B be two negative numbers. A is half of B. Which number is higher? [1]

A is higher than B. Half of a negative number is higher than the original number. For example:

B = -10

A is half of B so A = -5

A is higher than B.

1. Prove that the orbital speed of any satellite on a planet of mass M and radius R is given by [2]

See Part B Question 1.

1. I have an eraser of mass 30g and a text book of mass 1.5kg on my desk.
2. According to the universal formula, which item has a higher Eg? [1]

Eg = -GMm/r

Since Mdesk is higher, Eg(textbook) is lower (more negative). So, surprisingly, the Eg of the eraser is HIGHER than the Eg of the textbook. (NOTE - if we used Eg = mgh, the textbook would be higher Eg than the eraser).

1. Use your understanding of binding energy to explain why your answer to a) makes sense. [1]

At first, it doesn't make sense that Eg of the eraser is higher than Eg of a textbook. BUT - higher Eg means closer to zero. It means the eraser is less "in the hole" and would take less energy to send to infinity than a textbook. This makes more sense.

Mathematically, the Eb of the eraser is |Eg+Ek|. Since Ek is zero (not moving) the Eb of the eraser is |Eg| which is a smaller than for the textbook. Therefore the eraser is less bound than the textbook.

1. Suppose my desk is 1.0m tall. Show without calculating any values that the textbook would have more kinetic energy than the eraser if they both fell to the ground. [1]

E = E'

Eg + Ek = Eg' + Ek'

-GMm/R1 + 0 = -GMm/R2 + Ek'

Ek' = GMm/R2-GMm/R1

Ek' = GMm[1/R2 - 1/R1]

textbook is same as eraser, except for m

Ek'(text) = GM (mtext) [1/R2 - 1/R1]

Ek'(text) = GM (meraser) [1/R2 - 1/R1]

So since (mtext)> (meraser) then Ek'(text)>Ek'(eraser)

1. Prove that Ek = -1/2 Eg for a satellite in orbit. [3]

For a satellite in a circular orbit:

Fnet = mac

Fg = mac

GMm/r2 = mv2/r

Cancel the r -- but not the m!

GMm/r = mv2

Multiply both sides by 1/2

1/2GMM/r = 1/2 mv2

Left side is -1/2Eg, right side is Ek, therefore

-1/2 Eg = Ek

1. A problem asks to find the work done to lift an object on Earth. Bart calculates it using the local formula (W = ΔEg = mgh). Lisa calculates it using the universal formula.
2. whose answer is more correct? [1] Lisa's (the universal formula) Bart's formula assumes that g is constant, which it is not. g actually gets smaller as we get farther from the surface of the Earth, so Bart's answer will be a bit higher than the actual answer.
3. which answer is greater? [1] Bart's.
4. To calculate the work done to lift an object, the formula we used in grade 11 was Eg = mgh. Now we learn that work is ΔEg, not Eg. Why could we ignore the delta in grade 11? [1]

Work is ΔEg (when lifting things) or ΔEk (when speeding things up).

W = Eg2 - Eg1 = mgh2 - mgh1

We always set h1 to zero (usually at the ground level), so we get:

W = mgh2 or more simply : W = mgh

In other words, we omit the delta because we are always just subtracting zero.

We do the same thing with ΔEk, where the second Ek is zero because the object usually starts from rest.

W = 1/2 mv22 - 1/2 mv12

W = 1/2 mv22 - 0 = 1/2 mv22 or just simply W = 1/2 mv2